Telemedicine system based on radio cell phone technology

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Abstract – **This paper presents a system for transmitting ECG signals using recent cell phone technologies. The aim of the project is to give physicians and clinical staff the possibility to monitor homecare and emergency patients using telemetry. The acquired signals can be viewed at both ends of the system, i.e., transmitter and receiver. Before transmitting the signals, the system acquires them by using an acquisition board installed in a PC computer. The software for displaying these signals at both ends of the system provides an easy-to-use interface. The cell phone used is able to transmit data information with short delay time and to operate in radio-like mode.**
Keywords – **Telemedicine, cell phone, sample acquisition, emergency healthcare, monitoring, ECG signals.**

I. Introduction

The increasing advance in cellular technology has been helping biomedical practice to create important solutions. In telemedicine, its use has minimized the time necessary to transmit information between two distant points. The possibility of patients remote monitoring and diagnosis has shortened distances and increased the probability of successful emergency assistances. As heart attacks occur so frequently, quick attendance can be a great ally. In emergency situations (ambulances or even helicopters), a special cell phone having facilities to transmit data information and to operate in radio-like mode could be used. While the ambulance transports the patient to the hospital, his ECG signal may be transmitted in advance. So, the physician can care for his patient's health directly from the hospital or elsewhere saving significant time.

The aim of the proposed tele-ECG system is to provide a wireless solution to make patient's ECG signal available for monitoring and diagnosis although any sort of biological signal can be transmitted.

If an accident occurs in a highway out of the city, then the hospital emergency staff will be called. The struggle against time begins. The ambulance must arrive immediately to avoid patient's clinical situation to aggravate. When it arrives at the accident location, the tele-ECG system is placed on the victim at the same minute the paramedic, via radio, asks for permission to start transmitting the ECG signals. The reception software is triggered and set the cell phone configurations for auto-answering. When the system's reception module is ready for receiving those signals, the transmission software is launched and dials to the hospital's cell phone (or conventional line). Once both ends got connected, the acquisition process begins acquiring the ECG signal samples, automatically transferring them to the current serial port output buffer for transmission. At the receiving module, the signals that arrive at the cellular modem are transferred to the notebook serial port and reassembled on the screen for clinical monitoring and analysis.

This report is just one among several situations telemedicine could be used. Today's road-care companies in Brazil have to provide medical services in a wide range of roads. In developed countries, the use of homecare systems is increasing rapidly and is certainly a promise of a new concept of diagnosis and monitoring.

II. Methodology

The system uses a cell phone with facilities to transmit data information in modem-like mode, to communicate in radio-like mode and to be connected to a PC computer via an RS-232 interface. The computer used for transmitting the acquired ECG signal was a desktop PC. For the transmission link, a notebook should be better than a desktop due to its portability, versatility and weight. Nevertheless, the acquisition board involved in this project was a PCI acquisition board incompatible with notebooks. At the reception end, the system uses a notebook connected to another cell phone with the same facilities, thus, providing extra mobility for the system. Its interface must be physician-friendly, show data on the screen instantly and, in case of errors, present them clearly as proposed by [4].

The tele-ECG system was implemented using National Instruments LabVIEW 6i Evaluation System software, DT304 Data Translation Acquisition board and Motorola's i700 cell phone with iDEN technology. Fig.1 shows the system's context diagram.

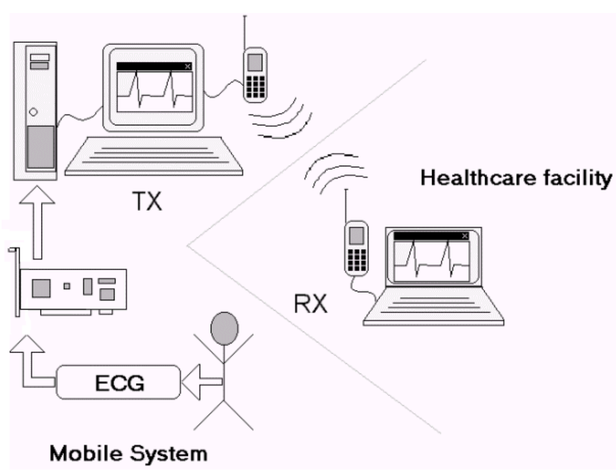

Fig.1 – System's context diagram

A. The Wireless Communicator

The wireless communicator proposed works in two different ways: cell phone mode and dispatch mode. It also operates with circuit data and packet data technologies. The developed

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system uses cell phones transmitting and receiving data in a circuit-data-oriented link, differently as proposed by [1] when TCP/IP was utilized over a packet-data communication. After they have established communication, the transmitting cell phone transmits the data arriving at its RS-232 serial port that was delivered by the acquisition software. A radio mode operation takes place before data transmission, when the paramedic asks for authorization to transmit the signals. The RS-232 interface can be easily found in PC-compatible computers and notebooks.

B. *The Data Acquisition (DAQ) Board*

The data acquisition system consists of a PCI DAQ board that is placed inside the computer, an external board for connecting the ECG signals, and a cable to connect both boards. The DAQ board proposed has an ADC resolution of 12-bits and a 400kS/s sampling frequency. The number of channels is another important characteristic when comparing DAQ boards. The tele-ECG system's DAQ board has 2 analog output channels, 16 single ended or 8 differential analog input channels and 23 digital I/O lines.

This paper presents the transmission of only one ECG lead, although it is intended to provide more signals as the bandwidth becomes wider. Another facility aimed is to transmit other biological signals together with ECG. All this improvements need a larger bandwidth and more channels in the DAQ board. So, although most biological signals are very low frequency, the board must have a high sampling frequency in order to deal successfully with all this incoming channels. The DAQ board sampling frequency is divided among each used channel. In the proposed case it operates with sample rate of 200 samples per second, sampling a unique single ended analog channel.

C. *The Software*

The software was implemented in LabVIEW development system that consists of building blocks each one performing small tasks concurrently in order to complete bigger tasks. Shown in Fig.2 is a simple scheme of significant tasks implemented. Developing code from the scheme illustrated in Fig.2 is very helpful because the LabVIEW block representation is very close to the one shown in that figure. There is also the Front Panel representing the user interface.

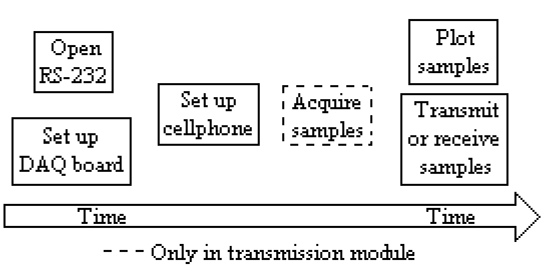

Fig.2 – Significant tasks

Firstly, a simple acquisition program was created. Basically it acquires the ECG signals arriving at the board, displays it on the screen (1000 samples/screen), opens the serial port and sends it to the currently open serial port. There are other controls in the transmission module in order to change and display currently open serial port, connection status, acquisition rate, transmission rate and heart activity frequency.

Secondly, the reception software receives the transmitted data at the serial port. The data arrive at the serial port, pass through a process that converts them into real voltage values and are reconstructed and plotted onto the screen.

Finally, it was developed the cell phone's setting up and transmission functions. Setting up functions put transmission and reception cell phones in the correct modes. After configuration, transmission functions were implemented for sending/getting the acquired binary data to/from the serial port.

III. Results

When testing the system, the results to be noted were the transmission rate, errors, system's speed and the range of the available covered area. Tests took place in Curitiba and São Paulo (400 km apart). Curitiba is initiating its infrastructure implantation while São Paulo has already a wide plant and covered area.

The tests performed in São Paulo proved the system could be used in 19,200 bps connections. The system's speed increased satisfactorily, sometimes refreshing the reception computer's screen in a way close to real ECG monitors. During transmission at that rate, however, the errors at the reception module had multiplied by a factor of two. So, despite of reaching an ideal rate of 19,200 bps, tests showed that the better and most reliable transmission rate was 9,600 bps.

Due to the limited bandwidth of 9,600 bps, the transmission occurred without any error correction protocols. Fig.3 illustrates the transmitted ECG signals plotted onto the transmission computer's screen.

Fig.3 – Transmitted ECG signal

The acquisition samples are 5s-long and it was chosen statistically. On the one hand, the system started becoming

slower and unstable with the acquisition of ECG signal samples greater than 5 seconds, i.e., errors become more frequent and the time for updating signals on the reception PC screen became greater. On the other hand, when the acquisition of ECG signal samples was smaller than 5 seconds the system become more speed and stable. The unique problem is that the reduced number of data displayed on the screen was not enough for analysis. The mean-point found was 5s-long samples.

At the reception module, the screen is updated approximately at the same rate as in the transmission module, occurring additional delay time in critical moments. Fig.4 shows the reception computer's screen and the received ECG signals.

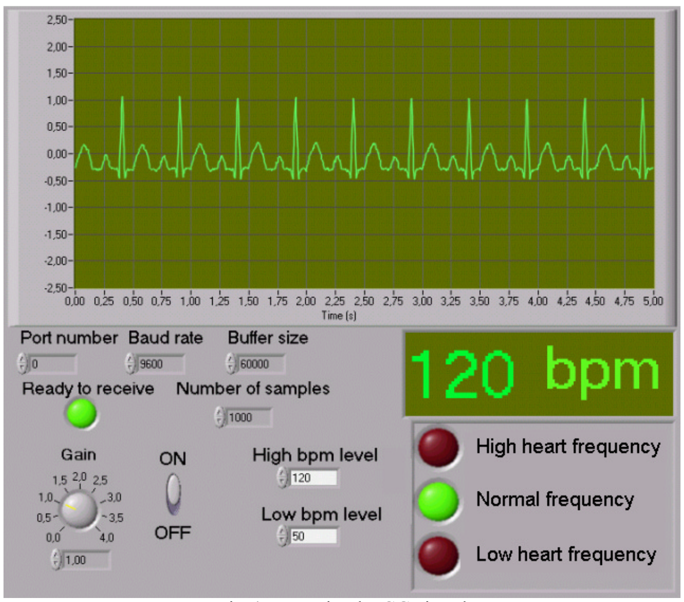

Fig.4 – Received ECG signal

IV. Discussion

The quality and strength of the signal received from the cellular base station can provoke transmission errors, delayed transmission and delay time while waiting for turning the connection up. Eventually, transmission errors can appear. It is worthy to remember that the signals being transmitted are not encoded. The system forces the bit stream to be flushed out through the serial port not worrying about loosing information. Hence performance can vary from place to place. Sometimes, the tele-ECG system seems not to work properly or even doesn't work. This is mostly due to shadow areas or uncovered areas (ROAMING) when the ambulance or helicopter is going through.

Reference [3] proposes an Internet based application for telemedicine that could be well implemented with this proposed tele-ECG system. It will just need to operate in packet-data communication instead of circuit-data. At the time of the implementation, the packet-data communication was not available for iDEN cell phone provider. WAP technology [2] could also be used in the communication between the emergency location and the hospital before transmitting the data signals.

Conclusion

Although those unwanted artifacts eventually happen, they will never keep the system from being used. However, the user must be aware of the region's signal coverage status.

While the signals are visually examined, they could be stored into a file or a central database [1]. Provided that there is available bandwidth to transmit more biological signals via RF or Internet, the tele-ECG system could be just a part of a more complete system. At the moment the system transmits just one heart signal but this number can rise up to 12 different heart signals. The actual bandwidth limitation tends to be well minimized as new technologies arrive into the world telecommunication market.

Actually, in less developed countries, homecare systems are not so popular and in certain cases it can be even not feasible, due to its actual high cost of implementation. In spite of this, there are lots of applications that telemedicine can be well used.

Without implementing error correction algorithms the system avoids redundant data transmission and makes good use of the scarce bandwidth that was available for the experimental tests. This boost in the rate transmission to the detriment of error correction is worthy, once the system's primary application is for patient's homecare monitoring and, secondarily, for accurate diagnosis when bigger resolution and fidelity are necessary.

The system's efficiency is directly linked with the RF signal quality supplied by the cellular provider. With the recent third generation cellular telephony technology, the bandwidth tends to rise and the system's resolution can be increased. Either the system will use error correction algorithms for enhancing data transmission reliability or packet-data communication with TCP/IP.

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